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RE TR 71-13

RUBBER PADS FOR TANK TRACK

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TECHNICAL REPORT

Edward W. Bergstrom
and
John R. Cerny

July 1971

RESEARCH DIRECTORATE

WEAPONS LABORATORY AT ROCK ISLAND

RESEARCH, DEVELOPMENT AND ENGINEERING DIRECTORATE

U. S. ARMY WEAPONS COMMAND

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13. ABSTRACT

Improved wear resistance of rubber track pads was sought. Continuing investigations of rubber compounding, service test evaluation, and rubber-to-metal bonding were made. The injection-molding of track pads was also attempted. Numerous compounds were developed for optimum properties, and track pads prepared from these compounds were service tested to determine actual wear resistance. Long-term aging tests on millable polyester urethane track pads and rubber-to-metal bonded specimens were completed. Compounds based on Stereon 750, HYTRANS elastomers, SBR/polybutadiene blends, and EPDM provided pads with improved tread wear. Little correlation was found between volume wear ratings based on service tests for cut crack growth, heat buildup, tear resistance; and abrasion resistance. Track pads prepared by injection molding had physical properties comparable to those of compression-molded pads. The preparation of rubber track pads, having significantly improved wear resistance, from certain low-cost, general-purpose type elastomers appears feasible. (U) (Edward W. Bergstrom and John R. Cerny)

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CONTENTS

ABSTRACT

Improved wear resistance of rubber track pads was sought. Continuing investigations of rubber compounding, service test evaluation, and rubber-to-metal bonding were made. The injection-molding of track pads was also attempted. Numerous compounds were developed for optimum properties, and track pads prepared from these compounds were service tested to determine actual wear resistance. Long-term aging tests on millable polyester urethane track pads and rubber-to-metal bonded specimens were completed. Compounds based on Stereon 750, HYTRANS elastomers, SBR/polybutadiene blends, and EPDM provided pads with improved tread wear. Little correlation was found between volume wear ratings based on service tests for cut crack growth, heat buildup, tear resistance; and abrasion resistance. Track pads prepared by injection molding had physical properties comparable to those of compression-molded pads. The preparation of rubber track pads, having significantly improved wear resistance, from certain low-cost, general-purpose type elastomers appears feasible.

OBJECTIVE

The object of this work was to develop improved rubber compounds for use in the fabrication of pads for tracked vehicles (such as the M60 tank and the M113 armored personnel carrier) and to correlate physical properties of the compounds with the service performance of the pads.

BACKGROUND

The development of a rubber track pad with improved tread wear would provide obvious tactical and logistical advantages for modern high speed tracked vehicles and would lead to savings in the cost of rubber components. The service life of rubber track pads in Vietnam has been reported to be less than 800 miles in the most adverse climatic conditions. The operational life of the T142 metal track (proposed to replace the T97E2 track used on the M48 and M60 series tanks) has been found to be 5000 miles or more. But the average life of the rubber pads has ranged from only 1200 to 3600 miles.[1] It would be desirable to have a track pad that would match the operational life of the track itself.

An intensive investigation of the means to improve the service life of rubber track pads has been conducted by this laboratory. Pads prepared from a millable polyester urethane, Genthane SR, exhibited significantly improved wear when compared with SBR control pads. Unfortunately, the high cost, the poor hydrolytic stability, and the tendency to become porous when tested at high speeds would appear to preclude the use of polyester urethanes in this application. Efforts have been concurrently underway to develop an improved pad from one or more of the less costly, general-purpose elastomers, especially those introduced within the past few years. Some results have been previously reported,[2-] and the results of additional work performed along these lines are included in this report.

APPROACH

Service tests of T130 and T142 track pads were arranged through the U. S. Army Tank-Automotive Command (ATAC), Warren, Michigan, and conducted at the Yuma Proving Ground, Yuma, Arizona, the FMC Corporation, San Jose, California, and ATAC.

The following wear rating was used to compare the performance of the rubber track pads tested:

$$\text{Volume Wear Rating} = \frac{\text{Average volume loss of commercial SBR control pads}}{\text{Average volume loss of experimental pads}} \times 100$$

Static exposure tests of T130 track pads in Panama were arranged through the cooperation of Dr. Leonard Teitell of the Pitman-Dunn Research Laboratories, Frankford Arsenal.

A Number 1 Banbury mixer was used to mix compounds selected for fabrication of track pads. The Banbury-mixed compound was then transferred to a 30-inch mill for additional mixing and sheeting-out. The cooled stock was later transferred to an 18-inch mill for warmup and sheeting-out to the desired thickness for the preparation of track pad preforms from rolled stock

The following surface preparations were performed on the track pad metal backup plates (inserts) and ASTM D429-64 steel test panels prior to their vulcanization-bonding to the rubber stocks: degreasing, glass beadblasting, solvent wiping, brush application of bonding agent, and drying.

Tensile strength, elongation, and modulus were determined at ambient and elevated temperatures by use of a Scott Model L-6 rubber tensile tester equipped with a Scott Model HTO hot tensile oven and autographic recorder-controller. Each tensile specimen was placed in the grips of the tester and conditioned for six minutes at the elevated temperature prior to being tested. All other physical properties were determined by ASTM procedures, where applicable.

A Lewis Vertical Rubber Injection Molding Machine (Model 200 V - RAN) was used in the study to determine the feasibility of preparing T130 track pads by injection-molding.

Compound formulations are given in Table I.

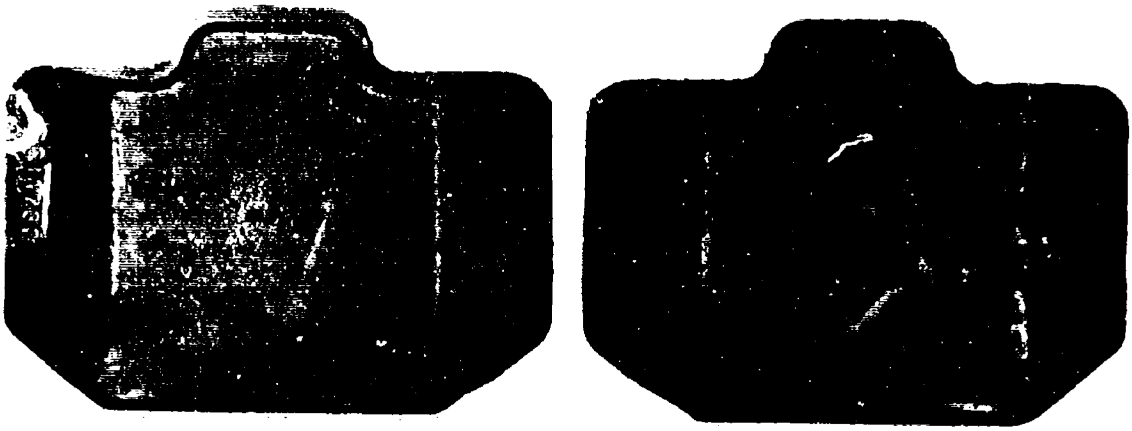
RESULTS AND DISCUSSION

Aging Studies

A previous report on this subject[7] gave the properties of T130 track pads prepared from a polyester urethane, Genthane SR, with and without an additive, after outdoor exposure to the open sun and rain forest in Panama for a period of one year. Results are now available on the properties of these pads after three years of exposure. The pads containing no hydrolysis inhibitor (Compound 1, Table I) had deteriorated (soft and tarlike) to such an extent that neither the physical properties of the rubber nor the rubber-to-metal bond strength of the pads could be determined. Physical properties of the pads containing a polycarbodiimide (PCD) hydrolysis inhibitor (Compound 2) are given in Table II. Significant deterioration of the pad surface was noted with more deterioration occurring in the pads exposed to the rain forest than in those exposed to the open sun. Visual examination of the pads exposed to the rain forest showed surface cracking and peeling. Photographs of both the inhibited and uninhibited pads after one and three years of aging in Panama are shown in Figures 1 and 2. Stirring rods were inserted into the interiors of the uninhibited pads aged three years and then partially withdrawn to show the soft and tarlike nature of the rubber. The rubber-to-metal bond strengths of the pads prepared from the inhibited compound are given in Table III. Bond strengths are holding up well, although some failure in the rubber-cover cement interface is now evident

In August 1963, a program was initiated in which commercial SBR T130 pads and T130 pads prepared from a polyester urethane, Genthane S, were exposed outdoors partially submerged in water. In December 1964, a T130 pad prepared from Genthane SR was added to the program. Shore A hardness measurements were made on the pads at various intervals until the tests were discontinued in September 1969 The results of this study are given in Table IV. The pads prepared from Genthane S (Compound 3) were spongy and gummy at the completion of the test, whereas the SBR pads remained virtually unchanged, i.e., changing only 6 to 7 points in hardness. The pads prepared from Genthane SR (Compound 1) had just begun to soften at the completion of the test.

In 1965, T142 track pads prepared from various urethane compounds were placed in indoor storage at this installation along with pads prepared from an SBR 1500 control compound to determine the aging resistance of the compounds under simulated warehouse conditions. In 1966, T142 pads prepared from Vibrathane 5004 urethane were also placed in storage. Storage temperatures reached extremes of 100°F - 120°F during July and August, and near freezing during the winter months of December, January, and February. All pads were removed from storage in the spring of 1970 after 55 months (pads exposed in 1965) and 48 months (pads exposed in 1966). Physical properties of the aged pads are given in Table V and show that the addition of a hydrolysis inhibitor significantly improves the tensile strength retention of the Genthane SR urethane pads during aging under these conditions. The tensile strength retention of the Genthane S urethane pads containing PCD hydrolysis inhibitor was also good. The tensile strength of uninhibited vulcanizates of Genthane S urethane is known to deteriorate rapidly when aged for only a short time (three years or less). The tensile retention of the Vibrathane 5004 urethane pads, even with PCD inhibitor, was not so good as it would have been if four parts of PCD inhibitor had been used instead of two parts. The rubber-to-metal bond strengths of the aged pads (Table VI) are compared with bond strengths observed during service testing of identical pads. All pads had equivalent or higher bond strengths after aging than originally, except for the Genthane SR urethane pads containing no hydrolysis inhibitor in which the Thixon P4/P3 system is utilized



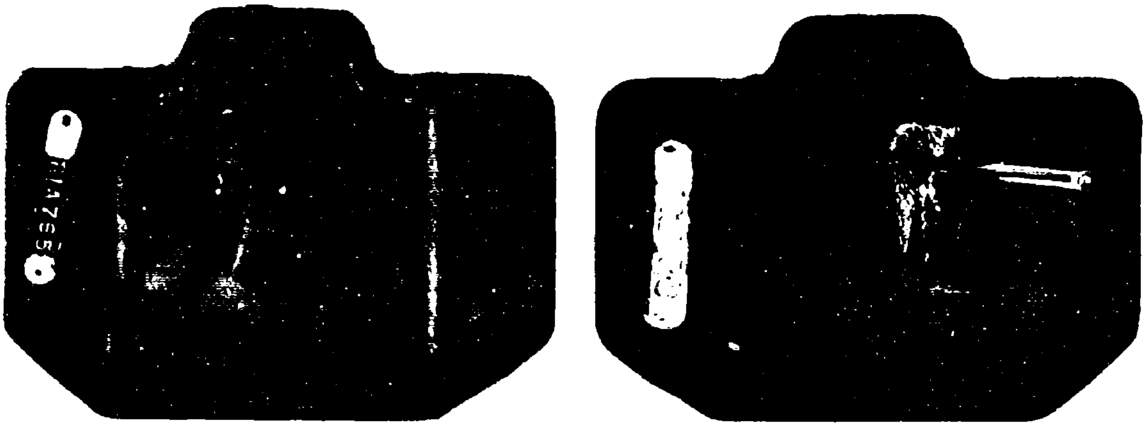
1 YEAR 3 YEARS

PANAMA - OPEN SUN EXPOSURE

1 YEAR 3 YEARS

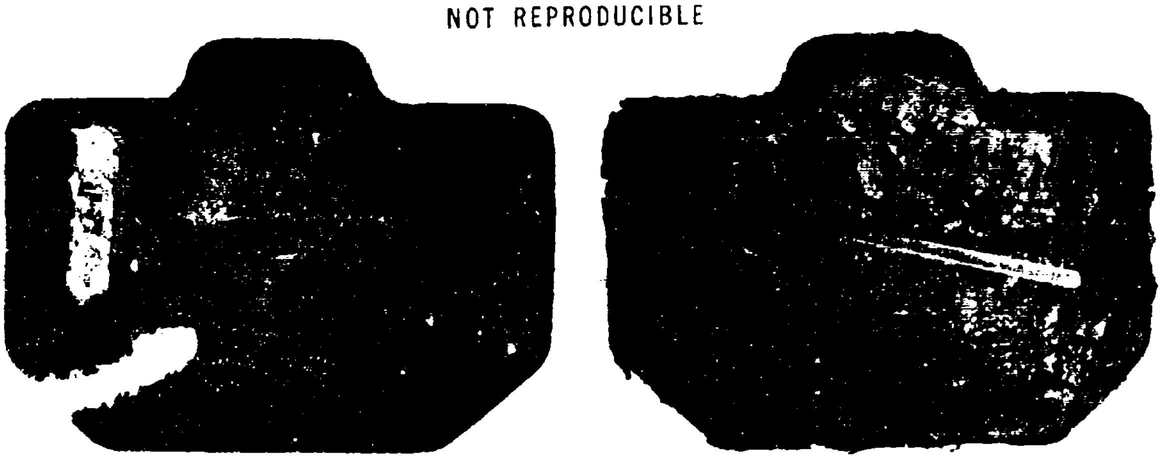
PANAMA - RAIN FOREST EXPOSURE

FIGURE 1 T130 TRACK PADS - POLYESTER URETHANE
(CONTAINS 4 PARTS PCD HYDROLYSIS INHIBITOR)



1 YEAR 3 YEARS
PANAMA - OPEN SUN EXPOSURE

NOT REPRODUCIBLE



1 YEAR 3 YEARS
PANAMA - RAIN FOREST EXPOSURE

FIGURE 2 T130 TRACK PADS - POLYESTER URETHANE
(CONTAINS NO HYDROLYSIS INHIBITOR)

The results obtained with the Genthane S urethane pads are of interest since the aged pads still retained the excellent rubber-to-metal bond strength after aging. However, all pads separated from the backup plates during the service test because of bond failure. The same bonding system was used with a Genthane SR urethane compound and no bond failures resulted during service testing. The rubber-to-metal bond strength of the pads prepared from Vibrathane 5004 increased significantly upon aging. Another excellent two-part system for bonding polyester urethanes to metal was reported in the previous report[7] on this subject. This was the Chemlok 205/TS-701-45 system.

The rubber-to-metal bond strength of several elastomers when bonded to ASTM D429-64 steel test panels with various bonding systems was determined after 30 months of shelf-aging indoors at this installation. These results are shown in Table VII. All bonds that were good originally (characterized by rubber failure rather than by bond failure) were also good after 30 months of aging (still characterized by rubber failure). Since this study of aging was initiated, a satisfactory bonding system has been found for chlorobutyl HT-1066. A Ty-Ply UP-BC system in which two coats of Ty-Ply BC were used over one coat of Ty-Ply UP, gives excellent results.

Compounding Studies

Compounding studies of several elastomers and blends of elastomers were made since the issuance of the previous report[7] on this subject. Track pads were prepared for service testing from the most promising compounds

Varying levels of an SAF carbon black were evaluated in a sulfur-accelerator cured SBR 1500 compound (Compounds 4, 14-16). The use of 45 parts black appeared to be optimum for this compound, although somewhat improved tear-resistance was obtained when 55 parts black were employed.

Stereon 720, a stereospecific SBR, was evaluated in blends with three different polybutadiene elastomers (Compounds 17-19). All compounds had significantly improved abrasion resistance when compared to an SBR control compound (No. 4) developed by this laboratory which has given wear ratings almost identical to those of commercial SBR control pads in several service tests. Tensile strength for the blended compounds is lower, however, than that found for the SBR control compounds.

A recently marketed oil-extended stereospecific SBR, Stereon 750, was also investigated, alone and blended with fast-curing EPDM (FC-EPDM) (Compounds 20 and 21). With both compounds, outstanding abrasion resistance was noted. The tear resistance and the tensile strength of the blended compound were inferior to those of the compound in which only Stereon 750 was used.

Several compounds with blends of oil-extended or nonoil-extended SBR and with oil-extended or nonoil-extended polybutadiene elastomers were evaluated. Track pads were prepared from three of these compounds (22-24). With Compound 23, exceptional resistance to cut crack growth was found. All compounds were found to have improved abrasion resistance when compared with the SBR control compound.

Samples of oil-extended and nonoil-extended alfin catalyzed copolymers of butadiene/styrene and butadiene/isoprene with high trans configurations were received from U. S. Industrial Chemicals Co. The tradename for these polymers is HYTRANS. An extensive evaluation was made of these elastomers for potential track pad use. The elastomers were evaluated alone, and in blends with polybutadiene and fast-curing EPDM. The nonoil-extended compounds (25 and 26) had properties generally similar to those of the SBR control compound, although the abrasion resistance of the compound prepared from the butadiene/isoprene copolymer was significantly better. The abrasion resistance of an oil-extended butadiene/isoprene compound (No. 27) was the best found for any compound (evaluated by this laboratory to date) and was significantly better than that of a corresponding oil-extended butadiene/styrene compound (No. 28). Both oil-extended compounds had better tear and crack growth properties than those of the corresponding nonoil-extended compounds. An examination of the oil-extended copolymers blended with polybutadiene (Compounds 29 and 30) shows that the abrasion resistance of the oil-extended butadiene/styrene copolymer blend (No. 30) is significantly better than that of the corresponding nonblended compound (No. 28). All alfin catalyzed copolymers can be provided excellent ozone resistance in both the accelerated and the outdoor tests when blended with fast-curing EPDM in 70/30 alfin catalyzed copolymer/FC-EPDM ratios.

E. I. DuPont de Nemours and Co submitted three compounds for track pad evaluation (Compounds 31-33). One compound is based on a 90/10 ECD-729/Nordel 1320 blend and the other two are based on 90/10 Neoprene GNA/Pale Crepe blends. Compound 32 exhibited significantly better crack growth resistance than the SBR control compound.

Rubber impregnated chopped continuous strand Fiberglas (treatment 065, Type A, one inch) was evaluated at concentrations of 2, 5 and 10 parts/100 rhc in SBR 1500, Stereon 750 and SBR 1500/polybutadiene compounds (No. 4, 20 and 22). The Fiberglas was added to the compounds on the mill near the end of the mixing cycle to prevent excessive breakdown of the fibers. The results of this evaluation are given in Table VIII. In every case, the tensile strength of the vulcanizates as well as resistance to cut crack growth decreased as the concentration of Fiberglas increased. Tear resistance, on the other hand, improved. In the case of the SBR 1500/polybutadiene blended compound, abrasion resistance was severely impaired by the addition of Fiberglas. Laminates were also formed with all compounds; 2, 5 and 10 parts/100 rhc of Fiberglas were placed between two uncured sheets of the rubber prior to curing. The tensile strengths of the laminates at ambient and elevated temperatures decreased as the concentration of Fiberglas increased.

Service Tests of Experimental Track Pads

Since issuance of the previous report,[7] experimental track pads prepared by this laboratory were evaluated in three service tests as follows:

Test Site	Track Pad Type	Scheduled Starting Date
Yuma Proving Ground, Yuma, Arizona	T142	November 1969
FMC Corporation, San Jose, California	T130	April 1970
U S. Army Tank-Automotive Command (ATAC), Warren, Michigan	T142	August 1970

At Yuma, a 775.6-mile road test was made involving the following conditions: gravel, 225 miles; level cross-country, 132 miles; and hilly cross-country, 418.6 miles. Experimental pads included in this test were prepared from chlorobutyl HT-1066, SBR 1500 containing various concentrations of carbon black and Elastothane ZR 625. The results of this test are given in Table IX. These results show that pads prepared from the SBR 1500 compound containing 55 parts SAF black had a higher wear rating than the commercial control pads and similar SBR 1500 pads containing lesser amounts of black. The Vibrathane ZR 625 pads factory produced from extruded stock also had a slightly higher wear rating than that of the commercial control.

Ninety experimental T130 track pads were evaluated at the FMC Corporation in a test conducted on vehicle M113A1 SJ-755 during a 4000-mile vehicle durability test. Wear ratings were determined on the experimental pads during the first 1500 miles of operation only (1000 miles on an asphalt-paved, 0.7-mile oval test track at 25 to 30 mph, followed by 500 miles on level dirt and gravel secondary roads). The experimental pads remained on the vehicle past the prescribed 1500-mile wear evaluation period to the end of the 4000-mile test. The results of this test are given in Table X and show that experimental pads prepared from two compounds, an ECD 729/Nordel 1320 blend and Stereon 750, had slightly higher wear ratings than those of the commercial control pads after 750 miles. However, none of the experimental pads had wear ratings higher than the commercial control after 1500 miles. FMC reported that chunking of the experimental pads prepared from the ECD 729/Nordel 1320 blend increased after 1500 miles to such an extent that the wear rating for these pads undoubtedly would have dropped below other pad groups if volume-loss data had been recorded at 4000 miles. Reduction in pad thickness was also checked by FMC to measure wear due to abrasion. The compounds were ranked best to worst by FMC on the basis of these measurements, as follows:

750 Miles	1500 Miles
Stereon 750	Stereon 750
Philprene 1609/Cis 4-1350	Philprene 1609/Cis 4-1350
ECD 729/Nordel 1320	ECD 729/Nordel 1320
SBR 4678/CB 221	SBR 4678/CB 221
Commercial Control	Commercial Control
SBR 1500/Diene	SBR 1500/Diene
Stereon 750/EP syn 55	Aged Commercial Control Pads
Neoprene GNA/Pale Crepe (Cpd. 32)	Neoprene GNA/Pale Crepe (Cpd. 33)
Neoprene GNA/Pale Crepe (Cpd. 33)	Stereon 750/EP syn 55
Aged Commercial Control Pads	Neoprene GNA/Pale Crepe (Cpd 32)

On the basis of thickness measurements, four compounds had better abrasion-resistance than that of the commercial control after both 750 miles and 1500 miles of testing.

Experimental T142 pads prepared from eight different compounds were service-tested on an M48 tank on the asphalt test track at ATAC. Results are shown in Table XI. All experimental pads except those prepared from the Neoprene GNA/Pale Crepe blends had wear ratings higher than those of the commercial control pads after a 250-mile test. Pads based on the HYTRANS elastomers, Stereon 750 and a SBR/Diene blend were significantly better after 750 miles.

On the basis of these service tests, preparation of track pads that will have wear resistance significantly better than that of currently used SBR commercial pads is apparently possible from certain lower cost, general-purpose elastomers.

Correlation of Laboratory Tests with Service Performance

In the previous report,[7] data were presented indicating that the service performance of millable polyester urethanes could be directly correlated with laboratory tests for stress-strain properties at elevated temperatures, crack growth (DeMattia), tear resistance (ASTM D624-54, Die C), heat buildup (Firestone Flexometer), and compression modulus (ASTM D575-67, Method A). The service performance of none of the other elastomers investigated, however, could be correlated with laboratory tests, except in the case of crack growth in which some correlation appeared to exist between compounds that exhibited extremely good crack growth of 3/32 or less after 50,000 cycles) or extremely poor (cracks across in less than 1500 cycles or so) crack-growth resistance. Since the program to develop track pads with improved wear-resistance could be accelerated if costly and time-consuming service tests were unnecessary, the results of the service tests conducted since the last report[7] were compared with the results of accelerated static and dynamic tests for any clue to possible correlation. These results are given in Table XII. No correlation appears to exist between volume-wear ratings based on service performance and the laboratory tests studied.

Injection-Molding Feasibility Studies

Because of the long, 75 minute, cure time required to compression-mold the thick sections of the T130 and T142 track pads, some effort was expended to determine the feasibility of preparing T130 track pads by injection molding. A T130 track pad mold was modified for injection molding, and attempts were made to prepare pads from the SBR 1500 control compound developed by this laboratory (Compound 4) with the Lewis Vertical Rubber Injection Molding Machine (Model 200 V-RAN) (48-ounce, mold-filling capacity) shown in Figure 3. Machine variables such as cylinder temperature, mold temperature, dwell time (mold), injection time, and injection pressure were varied until satisfactory test pads were obtained. The purpose of the initial efforts was to determine the state of cure of the pads when various mold temperatures and mold dwell times (cures) were used. Satisfactory pads for this purpose were prepared under the following conditions:

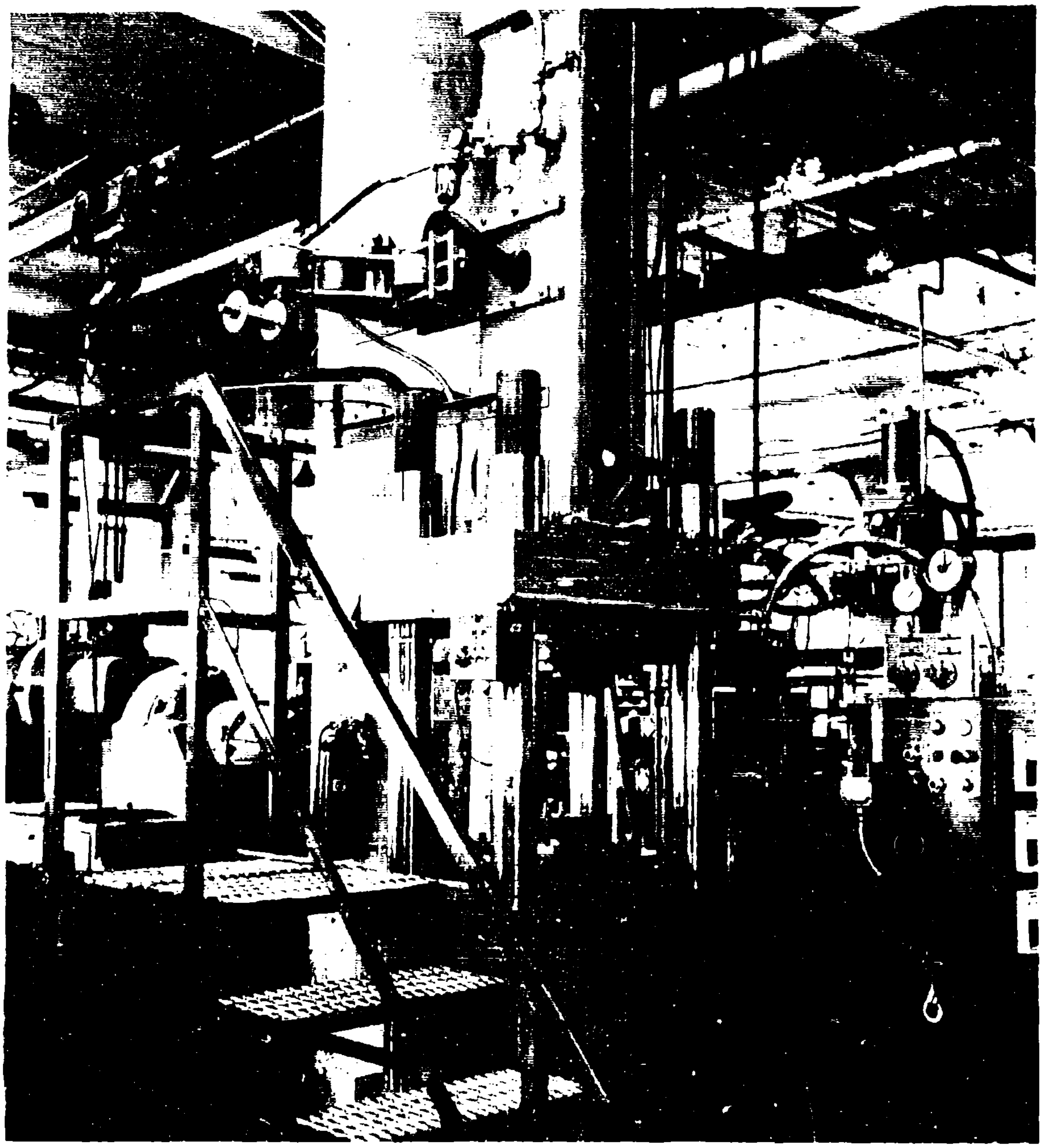


FIGURE 3 LEWIS VERTICAL RUBBER INJECTION MOLDING MACHINE
(MODEL 200V-PAN)

Machine Variables	1	2	3	4
	Conditions Used			
Cylinder temperature	150°F	150°F	150°F	150°F
Injection pressure	1700 psi	1700 psi	1700 psi	1700 psi
Injection time	30 sec	42 sec	48 sec	30 sec
Mold temperature	350°F	350°F	350°F	400°F
Dwell time	8 min	12½ min	15 min	5 min

A slight humping effect in a very small area of the pads around the gate opening at which the rubber is injected into the mold was evident in all pads. However, this was considered a minor problem, one that could be corrected by a change in the gate and nozzle openings. This has since been accomplished. Physical properties of sectioned track pads prepared under the conditions described above were determined, and results are shown in Table XIII in comparison with (1) a compression-molded 6-inch by 6-inch by .080-inch test pad and (2) a compression molded track pad. The T130 track pads having physical properties comparable to those of the compression molded pads apparently can be prepared by injection molding with dwell (cure) times of 5 to 10 minutes at 350°F or 400°F. The wear characteristics of injection-molded vs. compression-molded pads remain to be determined. From an economic standpoint, preparation of track pads would evidently be much less costly and time consuming by injection molding than by compression or transfer molding, provided that these pads are prepared one at a time. However, when pads are prepared by compression or transfer molding, the use of multiple cavity molds is not unusual, and six or eight cavity molds are commonly used. On the other hand, even a large size injection molding machine, such as the one used in this study, having a 48-ounce mold-filling capacity would allow for the preparation of only one pad at a time. The preparation of track pads by injection molding is, therefore, not as economic as it appears initially, especially, since manufacturers already have large sums of money invested in transfer and compression molding equipment.

Rubber-to-Metal Bonding Studies

The advance of the technology of rubber-to-metal vulcanization bonding has been considerable in the last few years in that many adhesive systems have been developed that have versatile processing latitudes as well as improved environmental resistance. A rubber-to-metal bonding test program was initiated to evaluate new bonding systems and to determine if these new systems could satisfy the stringent environmental requirements for functional rubber tank track pads.

The main objectives of this program were as follows:

1. To evaluate four commercial bonding systems for their ability to vulcanization bond various developmental tank track elastomeric compounds to 1020 steel.

2. To determine the effect of dioctyl-p-phenylene diamine and heliozone wax (a proven antiozonant system for unsaturated rubbers) on the 90° peel strength of the various compounds evaluated.

3. To determine whether bond strengths can be made more environmentally resistant by application of more adhesive or cover-coat than is recommended by the adhesive suppliers.

4. To determine the high temperature resistance of the bonding agents by measurement of the 90° peel strengths after the test specimens have been exposed for 10 minutes at 250°F (previous work has shown the importance of high-temperature bond retention in track pad applications).

The results of this study are shown in Table XIV. The rubber-to-metal bond failures are characterized by (1) the type of bond failure, i.e., R. - failure in the rubber and R C. - failure at the rubber-cover cement interface, and (2) the 90 degree peel strength in pounds per inch width, lb/in.

The results indicate that (1) bonding systems 1 and 2 are relatively unaffected by the antiozonant system used, whereas systems 3 and 4 are adversely affected by the addition of antiozonant to the rubber test compound, (2) in some cases, bond strength can be enhanced by the addition of extra coats of adhesive, whereas in other cases extra adhesive shows little or no significant bond improvement, (3) high-temperature stock break (S.B.) at 250°F is unassociated with adhesive bond failure but implies poor high-temperature tear strength of the particular rubber tested, (4) bonding system 2 appears to be the best all-around bonding system evaluated for unsaturated rubber compounds, and (5) bonding systems 2, 3, and 4 produced good bonds for specific unsaturated rubber compounds.

CONCLUSIONS

Track pads prepared from millable polyester urethanes exhibited significant deterioration in tensile strength upon aging, especially in Panama, even when hydrolytic inhibitors were added.

Compounds based on Stereon 750, HYTRANS copolymers of butadiene/styrene and butadiene/isoprene, SBR/polybutadiene blends and EPDM have exhibited some improvement in tread wear when compared with commercial SBR/500 control pads in service testing. Thus, preparation of track pa , may be possible from certain low cost, general-purpose elastomers (other than the conventionally used emulsion polymerized SBR) whose improvement in tread wear will match that of certain millable polyester urethanes.

Little correlation appears to be present between volume wear ratings based on service performance and laboratory tests used to measure cut crack growth, heat buildup, tear resistance, and abrasion resistance.

T130 track pads prepared by injection molding for as short a time as 5 to 10 minutes at temperatures of 350°F and 400°F have physical properties comparable to those of pads compression molded 75 minutes at 320°F.

RECOMMENDATIONS

Additional compounding studies should be performed on Stereon 750, the HYTRANS elastomers, SBR/polybutadiene blends, and EPDM to further improve the excellent tread-wear properties already found for pads prepared from these elastomers.

Wear characteristics of compression molded vs. injection molded track pads should be determined.

TABLE I

COMPOUND FORMULATIONS AND PHYSICAL PROPERTIES

Compounding Ingredients*	Parts by Weight 1	2	3	4	5	6	7	8	9	10	11
Genthane SR	100	100			100.2						
Genthane S			100			100					
SBR 1500				100				100			85
Vibrathane 5004							100				
Diene									100		
High Mooney EPDM									30		15
Chlorobutyl HT-1066										100	
Statex 160	40	40		45	30			55	45		45
Statex 125			30								
Philblack A						35					
Philblack O							40				
Kosmobile 77										65	
Cab-O-Sil H5											15
Zinc Oxide				4				3	3	5	3
Stearic Acid	0.2	0.4	0.2	2	0.2	0.2	0.25	1	2.6	1	1
Process Oil									10		
Santocure				1.5				0.5	1		0.5
Methyl Tuads										1	
Altax										1	
Magelite D										1	
Polycarbodiimide (PCD)		4				4	2				
Diisocyanate (TDI)					4						
Neozone D				1				1	2.5	1	1
DiCup 40 HAF							5				
DiCup 40C	7	8	8		5	5		4	3		4
Sulfur				2				0.2	1.75	0.5	0.2
U.O.P. 88				3							
Heliozone				1							
Agerite Resin D				1							
Cure (minutes @ Temp., °F)											
ASTM Test Pads	45@310	45@310	45@310	30@307	45@310	45@310	45@305	45@310	45@307	45@310	45@310
T130 or T142 Track Pads	75@320	75@320	150@292	75@320	75@320	75@320	75@320	75@320	75@320	75@320	75@320
Tensile, psi, ambient	4520	4430	5590	3630	6430	4000	3800	3890	3180	2670	3530
400°F	630	650	700	280	-	-	980	710	390	300	900
Ultimate Elong., %, ambient	500	520	400	515	510	470	420	500	550	480	450
400°F	340	350	225	165	-	-	280	240	210	200	230
Hardness, Shore A	70	75	69	68	77	73	76	69	61	68	72
Tear, Die C, pi	240	260	480	175	215	205	430	170	-	195	-
Crack Growth, DeMattia Tester, 50,000 cycles, 32nds of an inch	-	-	-	27	-	-	-	-	-	-	-
Abrasion Resistance, DuPont Abrader, Volume Loss after 25 min, cc, (% of SBR ref. cpd.)	-	-	-	1.267 (100)	-	-	-	-	-	-	-

*For more detailed description of elastomers, See Appendix.

TABLE I (Continued)

COMPOUND FORMULATIONS AND PHYSICAL PROPERTIES

Compounding Ingredients	12	13	14	15	16	17	18	19	20	21	22
	Parts by Weight										
SBR 1500	75	100	100	100	100						75
Diene	25						30				25
Stereon 720						70	70	70			
CB 221 Polybutadiene						30					
Cis 4-1350 Polybutadiene								64.5			
Stereon 750									137.5	96.25	
EP syn 55 EPDM										30	
Statex 160	40	45	25	35	55	50	50	26		55	
Cab-O-Sil H5	15	15									
Statex 125									70		
Philblack E											45
Stearic Acid	1	1	2	2	2	2.6	2.6	2.6	2	2	2
Zinc Oxide	3	3	4	4	4	3	3	3	2	3	4
Santocure	0.5	0.5	1.5	1.5	1.5	1.1	1.1	1.1	1.4	0.5	1.5
Neozone D	1	1	1	1	1	1	1	1	1	1	1
Heliozone			1	1	1	1	1	1	1		1
Agerite Resin D			1	1	1						1
Sulfur	0.2	0.2	2	2	2	2	2	2	1.7	0.2	2
DiCup 40C	4	4								5	
U.O.P. 88			3	3	3	5	5	5	5		5
Cure (*minutes @ Temp., °F*)											
ASTM Test Pads	45@310	45@307	45@310	45@310	45@310	45@310	45@310	45@310	30@307	30@307	30@307
T130 or T142 Track Pads	75@320	75@320	75@320	75@320	75@320	75@320	75@320	75@320	75@320	75@320	75@320
Tensile, psi, *ambient*	3300	3560	3040	4000	4200	2290	2960	2500	2660	2200	3340
400°F	800	820	240	340	540	510	540	380	490	620	465
Ultimate Elong., %, ambient	440	470	590	560	470	490	650	720	670	490	460
400°F	200	210	140	160	170	330	400	480	380	250	180
Hardness, Shore A	71	72	55	60	72	72	72	66	58	62	65
Tear, Die C, pi	-	-	140	165	190	205	215	195	235	170	190
Crack Growth, DeMattia Tester, 50,000 cycles, 32nds *of an* inch	-	-	Cracked across <50,000 cycles	Cracked across <40,000 cycles	Cracked across <40,000 cycles	Cracked across <20,000 cycles	25	16	23	Cracked across <50,000 cycles	27
Abrasion Resistance, DuPont Abrader, Volume Loss after 25 min., cc, (% of SBR ref. cpd.)	-	-	-	-	-	0.349 (363)	0.260 (487)	0.168 (754)	0.179 (707)	0.145 (874)	1.094 (116)

TABLE I (Continued)

COMPOUND FORMULATIONS AND PHYSICAL PROPERTIES

Compounding Ingredients	Parts by Weight										
	23	24	25	26	27	28	29	30	31	32	33
Philprene 1609	101.5										
Cis 4-1350 Polybutadiene	64.5										
CB 221 Polybutadiene		30									
Diene							30	30			
SBR 4678		101.5									
HYTRANS 1227-158-7			100								
HYTRANS 1227-158-6				100							
HYTRANS 1227-158-4							96.25				
HYTRANS 1227-176-1						137.5					
HYTRANS 1227-176-2					137.5						
HYTRANS 1227-158-2								96.25			
EC[illegible]29									90		
Nordel 1320									10		
Neoprene GNA										90	90
Pale Crepe										10	10
Statex 160		10	45	45	70	70	70	70			
ISAF Carbon Black									100	20	20
Zinc Oxide	3	3	4	4	4	4	4	4	5	5	5
Stearic Acid	2	2.6	2	2	2	2	2	2	1	1	0.5
Piccopale 100 resin	5										
Santoflex AW	1.5										
Thermoflex A	1										2
Akroflex CD										2.5	3
Akroflex AZ										1	
Neozone D		1	1	1	1	1	1	1			
MBT									0.7		
MBTS										0.5	0.5
Thionex									1.5		
Santocure	1	1.1	1.5	1.5	1.5	1.5	1.5	1.5			
Sulfur	1.5	2	2	2	2	2	2	2	1.5		
Magnesium oxide										4	4
Hi Sil 233										20	40
Graphite										3	6
Flexon 765									65		
U.O.P. 88	3	5	5	3	5	5	5	5			
Heliozone	1	1	1	1	1	1	1	1			
Dioctyl Sebacate										10	10
Cure (minutes @ Temp., °F)											
ASTM Test Pads	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	30@307	35@307	35@307
T130 or T142 Track Pads	75@320	75@320	75@320	75@320	75@320	75@320	75@320	75@320	75@320	75@320	75@320
Tensile, psi, ambient	2820	2830	2900	3970	3130	2860	2940	2910	2920	2865	2495
400°F	430	380	630	460	540	470	560	590	480	475	550
Ultimate Elong., %, ambient	860	580	520	570	740	760	570	660	470	610	500
400°F	435	200	320	220	400	400	300	360	230	300	300
Hardness, Shore A	55	58	62	65	56	56	62	60	65	60	72
Tear, Die C, pi	220	205	210	205	220	235	180	190	155	220	245
Crack Growth, DeMattia Tester, 50,000 cycles, 32nds of an inch	4	27	21	18	14	5	18	9	16	4	18
Abrasion Resistance, DuPont Abrader, Volume Loss after 25 min., cc. (% of SBR ref. cpd.)	0.402 (315)	0.529 (240)	0.835 (152)	1.266 (100)	0.068 (1858)	0.434 (283)	0.091 (1392)	0.154 (823)	1.249 (101)	1.263 (100)	1.325 (96)

TABLE II

PROPERTIES OF PCD-INHIBITED POLYESTER URETHANE T130 RUBBER TRACK PADS
AFTER THREE YEARS OF OUTDOOR EXPOSURE IN PANAMA

		Exposed Three Years in Rain Forest				
Properties Tested	Unaged Pad (Average of 9 Consecutive Slices)	Slice 1 (Surface)	Slices 2-4	Slices 5-7	Slices 8-10	Slices 11, 12 (Approximate Middle of Pad)
Tensile, psi	4470	520	3230	4460	4360	4340
Modulus @ 300% Elongation, psi	1740	-	2490	2520	2480	2410
Ultimate Elongation, %	540	250	370	470	470	470
Hardness, Shore A	69	75	72	72	70	70

		Exposed Three Years in Open Sun				
Properties Tested	Unaged Pad (Average of 9 Consecutive Slices	Slice 1 (Surface)	Slices 2-4	Slices 5-7	Slices 8-10	Slices 11 - 13 (Approximate Middle of Pad)
Tensile, psi	4470	3280	4530	4440	4570	4460
Modulus @ 300% Elongation, psi	1740	2440	2470	2620	2540	2560
Ultimate Elongation, %	540	400	490	470	480	470
Hardness, Shore A	69	76	70	70	70	70

NOTE: Pads were sliced into 0.075 inch slices in a direction parallel to the face of the pad.

TABLE III

RUBBER TO METAL BOND STRENGTH OF PCD
INHIBITED POLYESTER URETHANE T130 RUBBER
TRACK PADS AFTER THREE YEARS EXPOSURE IN PANAMA

Exposure Conditions	90 Degree Peel Strength*, lb/in	Type of Failure, Percent R**	RC***
Unaged	175-200	100	0
Aged 3 years in open sun at Panama	220	75	25
Aged 3 years in rain forest at Panama	200	85	15

*Bonding system - Thixon P4/XAB936/Mondur TM

**R indicates rubber failure

***RC indicates failure in the rubber-cover cement interface

TABLE IV

CHANGE IN SHORE A HARDNESS OF T130 TRACK PADS
EXPOSED OUTDOORS AT ROCK ISLAND, ILLINOIS
PARTIALLY SUBMERGED IN WATER (OR ICE)* FOR SIX YEARS

	Shore A Hardness					
	Genthane SR (Polyester Urethane)	Genthane S (Polyester Urethane)			Commercial SBR	
Aging Time (Months)	#1	#1	#2	#3	#1	#2
Original (Unaged)	68	67	67	66	72	72
12	68	65	66	64	77	78
24	68	56	58	54	74	74
34	68	-	-	-	-	-
38	-	53	52	50	79	78
49	68	43	44	43	78	78
57	60	-	-	-	-	-
72	-	Gummy	Gummy	Gummy	76	75

*Pads were generally encased in ice from December through February of each year.

TABLE V

PHYSICAL PROPERTIES OF T142 TRACK PADS STORED INDOORS

SBR 1500 (Control)[1]

Properties Tested	Unaged Pad (Average of 9 Consecutive Slices)	Exposed 55 Months: Slice 1 (Surface)	Exposed 55 Months: Slices 2-5	Exposed 55 Months: Slices 6-9
Tensile, psi	3270	3110	3280	3380
Modulus @ 300% Elongation, psi	1640	2350	2270	2150
Ultimate Elongation, %	485	380	390	420
Hardness, Shore A	66	67	64	62

Genthane SR (Urethane - Contains no Hydrolysis Inhibitor)[2]

Properties Tested	Unaged Pad (Average of 9 Consecutive Slices)	Exposed 55 Months: Slice 1 (Surface)	Exposed 55 Months: Slices 2-5	Exposed 55 Months: Slices 6-9
Tensile, psi	4740	2490	2700	3440
Modulus @ 300% Elongation, psi	2190	1040	1110	1750
Ultimate Elongation, %	510	670	650	570
Hardness, Shore A	68	57	61	64

TABLE V (Continued)

PHYSICAL PROPERTIES OF T142 TRACK PADS STORED INDOORS

Genthane SR (Urethane - Contains 4 parts/100 rhc TDI Hydrolysis Inhibitor)[3]

Properties Tested	Unaged Pad (Average of 9 Consecutive Slices)	Exposed 55 Months		
		Slice 1 (Surface)	Slices 2-5	Slices 6-9
Tensile, psi	6430	6400	6310	6130
Modulus @ 300 % Elongation, psi	3000	3850	3760	3540
Ultimate Elongation, %	510	430	440	450
Hardness, Shore A	77	76	76	76

Genthane S (Urethane - Contains 4 parts/100 rhc Hydrolysis Inhibitor)[4]

Properties Tested	Unaged Pad (Average of 9 Consecutive Slices)	Exposed 55 Months		
		Slice 1 (Surface)	Slices 2-5	Slices 6-9
Tensile, psi	4000	3850	3800	3690
Modulus @ 300 % Elongation, psi	2500	3230	2760	2810
Ultimate Elongation, %	470	380	410	400
Hardness, Shore A	73	71	70	69

TABLE V (Continued)

PHYSICAL PROPERTIES OF T142 TRACK PADS STORED INDOORS

Vibrathane 5004 (Urethane - Contains 2 parts/100 rhc PCD Hydrolysis Inhibitor)[5]

Properties Tested	Unaged Pad (Average of 9 Consecutive Slices)	Exposed 48 Months: Slice 1 (Surface)	Exposed 48 Months: Slices 2-5	Exposed 48 Months: Slices 6-9
Tensile, psi	3310	2320	3050	3140
Modulus @ 300% Elongation, psi	2410	2270	2540	2560
Ultimate Elongation, %	465	310	440	450
Hardness, Shore A	75	72	70	68

NOTE: Pads were sliced into 0.075-inch slices in a direction parallel to the face of the pad

[1] Compound 4 - Table I
[2] Compound 1 - Table I
[3] Compound 5 - Table I
[4] Compound 6 - Table I
[5] Compound 7 - Table I

TABLE VI

RUBBER-TO-METAL BOND STRENGTH OF T142 TRACK PADS
(EXPOSED INDOORS)

Compound	Description	Bonding System	Original 90-Degree Peel Strength, pi	Service Test Performance	90-Degree Peel Strength After 55 Months of Indoor Aging, pi
4	SBR 1500 (Control)	Chemlok 205/220	220-225	1 or 2 out of 20 pads exhibited bond failure at 1150 miles	280-285 (Rubber Failure)
1	Genthane SR (Contains no hydrolysis inhibitor)	Thixon P4/P3	250-275	15 out of 32 pads exhibited bond failure at 1150 miles	50-70 (Bond Failure-Rubber to cover coat)
5	Genthane SR (Contains 4 parts/100 rhc TDI hydrolysis inhibitor)	Thixon XD 9777/ XAB 936	250	No bond failures at 1150 miles	350 (Rubber Failure)
6	Genthane S (Contains 4 parts/100 rhc PCD hydrolysis inhibitor)	Thixon XD 9777/ XAB 936	250-275	All pads lost at 1150 miles due to bond failure	275 (Rubber Failure)
7	Vibrathane 5004 (Contains 2 parts/100 rhc PCD hydrolysis inhibitor)	Hughson EX-B102-5	100-125	Not tested	350 (Rubber Failure-48 months)

TABLE VII

RUBBER-TO-METAL BOND STRENGTH OF VARIOUS ELASTOMERS AFTER 30 MONTHS OF SHELF-AGING

Compound	Elastomer	Bonding System	Original 90-Degree Peel Strength, pi	Type of Failure*	90-Degree Peel Strength After 30 Months Shelf Aging, pi	Type of Failure*
1	Genthane SR (Urethane)	Thixon P4/XAB 936	145	BF	155	RF
1	Genthane SR (Urethane)	Thixon P4/XAB 936/Mondur TM	175	RF	150	RF
1	Genthane SR (Urethane)	Chemlok 205/TS-701-45	170	RF	155	RF
1	Genthane SR (Urethane)	Chemlok 205/TS-701-46	200	RF	175	RF
4	SBR 1500 (Antiozonant plus Wax)	Chemlok 205/220 (1 coat 220)	75	BF	65	BF
4	SBR 1500 (Antiozonant plus Wax)	Chemlok 205/220 (2 coats 220)	90	B/RF	135	B/RF
4	SBR 1500 (Antiozonant plus Wax)	Chemlok 205/220 (3 coats 220)	140	RF	140	RF
8	SBR 1500 (Peroxide Cure)	Chemlok 205/220 (1 coat 220)	115	RF	150	RF
8	SBR 1500 (Peroxide Cure)	Chemlok 205/220 (2 coats 220)	115	RF	175	RF
9	Polybutadiene/HM-EPDM	Chemlok 205/220	145	RF	145	RF
10	Chlorobutyl HT-1066	Chemlok 205/231	41	BF	60	BF
11	SBR 1500/HM-EPDM	Chemlok 205/220	135	RF	130	RF
12	SBR 1500/Polybutadiene	Chemlok 205/220	160	RF	190	RF
13	SBR 1500 (Peroxide Cure)	Chemlok 205/220	135	RF	135	RF

* BF - Bond Failure
RF - Rubber Failure
B/RF - Part Bond/Part Rubber Failure

NOTE: One coat each of prime and cover coats were used except as indicated.

TABLE XIII

EVALUATION OF RUBBER IMPREGNATED CHOPPED FIBERGLAS STRANDS IN VARIOUS RUBBER COMPOUNDS

Properties Tested	SBR 1500 (Compound 4) No Fiberglas (Control)	2 Parts Fiberglas	5 Parts Fiberglas	10 Parts Fiberglas	Stereon 750 (Compound 20) No Fiberglas (Control)	2 Parts Fiberglas	5 Parts Fiberglas	10 Parts Fiberglas	75/25 SBR 1500/Diene Blend (Compound 22) No Fiberglas (Control)	2 Parts Fiberglas	5 Parts Fiberglas	10 Parts Fiberglas
Tested @ Ambient												
Tensile, psi	4200	2520	2110	2090	2760	1560	1300	1180	3500	2650	2100	1940
Modulus @ 100% Elongation, psi	350	575	740	910	330	490	460	470	450	450	710	890
Modulus @ 200% Elongation, psi	990	1100	1210	1300	520	680	740	710	960	980	1130	1300
Modulus @ 300% Elongation, psi	1930	2150	2090	2040	860	1020	1030	940	1950	1910	1840	1830
Ultimate Elongation, %	510	360	330	310	750	470	390	370	450	380	330	310
Hardness, Shore A	65	[illegible]	74	80	60	66	70	75	65	68	73	78
Tested @ 400°F												
Tensile, psi	330	280	270	440	520	240	230	270	580	285	340	330
Modulus @ 100% Elongation, psi	240	240	-	-	140	190	180	230	270	280	340	-
Modulus @ 200% Elongation, psi	-		-	-	220	-	-	-	580	-	-	-
Modulus @ 300% Elongation, psi	-				420	-	-		-	-	-	-
Ultimate Elongation, %	160	120	60	50	350	180	130	120	200	100	100	90
Tear, Die C, pli, ambient	190	245	280	320	220	260	290	315	220	210	285	295
Firestone Flexometer, 0.25 inch throw, 690 lb load, Time to go from 100-200°F, minutes	23.7	23.4	45.0	60.5	8.6	12.0	18.1	26.6	11.2	16.7	24.7	28.2
Crack Growth, DeMattia Tester 50,000 cycles, 32nds of an inch	23	Cracked across 40,000 cycles	Cracked across 30,000 cycles	Cracked across <10,000 cycles	27	Cracked across <50,000 cycles	Cracked across <40,000 cycles	Cracked across <40,000 cycles	19	Cracked across <50,000 cycles	Cracked across <40,000 cycles	Cracked across <30,000 cycles
Abrasion Resistance, DuPont Abrader, Volume Loss after 25 min., cc (% of SBR Ref.Cpd.)	1.300 (100)	1.261 (101)	1.282 (101)	1.280 (102)	0.133 (1049)	0.123 (1061)	0.109 (1194)	0.113 (1149)	0.119 (1092)	0.281 (462)	0.815 (156)	1.129 (115)

TABLE IX

RESULTS OF T142 TRACK PAD TEST AT YUMA PROVING GROUND

Compound	Description	No. of Pads	Volume Wear Rating (775.6 Miles)
14	SBR 1500 (25 parts SAF Black)	8	65
15	SBR 1500 (35 parts SAF Black)	8	77
4	SBR 1500 (45 parts SAF Black)	8	87
16	SBR 1500 (55 parts SAF Black)	8	110
10	Chlorobutyl HT-1066	7	73
-	Vibrathane ZR 625	Unknown*	101
-	Commercial Control Pads	Unknown	100

*Furnished by U. S. Army Tank-Automotive Command

TABLE X

RESULTS OF T130 TRACK PAD TEST AT THE FMC CORPORATION

Compound	Description	No. of Pads	Volume Wear Rating 750 Miles	1500 Miles
31	90/10 ECD 729/Nordel 1320	10	102	99
20	Stereon 750	10	101	94
-	Commercial Control Pads	Unknown	100	100
23	101.5/64.5 Philprene 1609/cis 4-1350	10	96	94
24	101.5/30 SBR 4678/CB 221	10	89	89
-	Commercial Control Pads (aged 7 years)	10	88	92
22	75/25 SBR 1500/Diene	10	87	88
21	96.25/30 Stereon 750/EP syn 55	10	76	76
33	90/10 Neoprene GNA/Pale Crepe	10	75	79
32	90/10 Neoprene GNA/Pale Crepe	10	74	77

TABLE XI

RESULTS OF T142 TRACK PAD TEST AT ATAC

Compound	Description	No. of Pads	Volume Wear Rating 250 Miles	500 Miles	750 Miles
28	HYTRANS 1227-176-1 (Butadiene/Styrene Copolymer)	8	129	122	124
22	75/25 SBR 1500/Diene	8	127	118	117
20	Stearon 750	9	124	112	110
27	HYTRANS 1227-176-2 (Butadiene/Isoprene Copolymer)	8	123	119	127
23	101.5/64.5 Philprene 1609/cis 4-1350	8	109	100	100
31	90/10 ECD 729/Nordel 1320	8	106	98	98
-	Commercial Control Pads	Unknown	100	100	100
32	90/10 Neoprene GNA/Pale Crepe	6	39	40	41
33	90/10 Neoprene GNA/Pale Crepe	6	38	41	42

TABLE XII

SERVICE PERFORMANCE VS. CRACK GROWTH, TEAR RESISTANCE, HEAT BUILDUP, ABRASION RESISTANCE, COMPRESSION MODULUS, AND TENSILE STRENGTH AT AMBIENT AND ELEVATED TEMPERATURES

Compound	Description	Crack Growth[1]	Tear, pi, Die C	Heat Buildup[2]	Abrasion Resistance[3]	Compression Modulus, psi	Tensile Strength, psi, Ambient	Tensile Strength, psi, at 400°F	Volume Wear Rating
28	HYTRANS 1227-176-1 (Butadiene/ Styrene Copolymer)	5	235	8.4	0.434 (283%)	175	2860	470	129
27	HYTRANS 1227-176-2 (Butadiene/ Isoprene Copolymer)	14	220	9.5	0.068 (1858%)	255	3130	540	123
16	SBR 1500 (55 parts SAF Black)	Cracked across <40,000 cycles	190	13.6		365	4200	540	110
20	Stereon 750	23	235	7.7	0.179 (707%)	240	2660	490	109
22	75/25 SBR 1500/Diene	27	190	26.4	1.094 (116%)	355	3340	465	106
31	90/10 ECD 729/Nordel 1320	16	155	15.4	1.249 (101%)	290	2920	480	103
23	101.5/64.5 Philprene 1609/cis 4-1350	4	220	6.2	0.402 (315%)	195	2820	430	102
24	101.5/30 SBR 4678/CB 221	27	205	15.7	0.529 (240%)	205	2850	380	89
21	96.25/30 Stereon 750/EP syn 55	Cracked across <50,000 cycles	170	16.2	0.145 (874%)	260	2200	620	76
10	Chlorobutyl HT-1066	4	195	14.0	1.330 (95%)	260	2670	300	73
32	90/10 Neoprene GNA/Pale Crepe	4	220	27.6	1.263 (100%)	275	2865	475	59
33	90/10 Neoprene GNA/Pale Crepe	15	245	10.7	1.325 (96%)	390	2495	550	57

[1] Crack Growth, DeMattia Tester 50,000 cycles, 32nds of an inch

[2] Heat Buildup, Firestone Flexometer, 0.25 inch Throw - 600 lb. load, Time to go from 100-200°F, Minutes

[3] Abrasion Resistance, DuPont Abrader, Volume Loss after 25 min. cc, (% of SBR ref. 590)

TABLE XIII

STATE OF CURE OF INJECTION MOLDED T130 TRACK PADS

6-inch by 6-inch by .080-inch Test Pad, Cured 45 min. at 310°F in Steam Press

Properties Tested	
Tensile, psi	3890
Modulus @ 100% Elongation, psi	320
Modulus @ 200% Elongation, psi	790
Modulus @ 300% Elongation, psi	1710
Ultimate Elongation, %	500
Hardness, Shore A	63

T130 Track Pad - Cured 75 min. at 320°F in Steam Press

Properties Tested	Slices 1-4	Slices 5-7	Slices 8-10
Tensile, psi	3710	3650	3670
Modulus @ 100% Elongation, psi	340	320	290
Modulus @ 200% Elongation, psi	770	750	830
Modulus @ 300% Elongation, psi	1660	1680	1770
Ultimate Elongation, %	480	480	480
Hardness, Shore A	59	59	59

T130 Track Pad - Injection Molded; Dwell Time, 8 min., Mold Temp. 350°F

Properties Tested	Slices 1-4	Slices 5-7	Slices 8-10
Tensile, psi	3030	3130	3000
Modulus @ 100% Elongation, psi	320	340	310
Modulus @ 200% Elongation, psi	850	870	860
Modulus @ 300% Elongation, psi	1830	1880	1850
Ultimate Elongation, %	430	430	430
Hardness, Shore A	60	59	59

TABLE XIII (Continued)

STATE OF CURE OF INJECTION MOLDED T130 TRACK PADS

T130 Track Pad - Injection Molded; Dwell Time, 12-1/2 min., Mold Temp. 350°F

Properties Tested	Slices 1-4	Slices 5-7	Slices 8-10
Tensile, psi	3100	3050	2960
Modulus @ 100% Elongation, psi	440	410	360
Modulus @ 200% Elongation, psi	1350	1120	1000
Modulus @ 300% Elongation, psi	2600	2080	2080
Ultimate Elongation, %	360	360	380
Hardness, Shore A	60	60	59

T130 Track Pad - Injection Molded; Dwell Time, 15 min., Mold Temp. 350°F

Properties Tested	Slices 1-4	Slices 5-7	Slices 8-10
Tensile, psi	3330	3460	3460
Modulus @ 100% Elongation, psi	540	460	360
Modulus @ 200% Elongation, psi	1340	1150	980
Modulus @ 300% Elongation, psi	2550	2250	2100
Ultimate Elongation, %	390	410	420
Hardness, Shore A	60	60	60

T130 Track Pad - Injection Molded; Dwell Time, 5 min., Mold Temp. 400°F

Properties Tested	Slices 1-4	Slices 5-7	Slices 8-10
Tensile, psi	3290	3450	3310
Modulus @ 100% Elongation, psi	350	390	410
Modulus @ 200% Elongation, psi	890	850	840
Modulus @ 300% Elongation, psi	1950	1670	1580
Ultimate Elongation, %	470	500	520
Hardness, Shore A	58	58	58

NOTE: All test pads and track pads prepared from the same Bandury mixed batch of compound. Pads were sliced 0.075 inch slices in a direction parallel to the face of the pad.

TABLE XIV RUBBER-TO-METAL BOND STRENGTH OF VARIOUS ELASTOMERIC COMPOUNDS BONDED TO 1020 STEEL WITH FOUR DIFFERENT BONDING SYSTEMS AND TESTED AT ROOM TEMPERATURE AND AT ELEVATED TEMPERATURES[1]

90 DEGREE PEEL STRENGTH (LB/IN) - TYPE OF FAILURE [2]

BONDING SYSTEMS	[3] ADHESIVE APPLICATION SCHEME	COMPOUND 20 (SOLUTION POLYMERIZED S.B.R.) WITH ANTIOZONANT R.T.	COMPOUND 20 WITH ANTIOZONANT 250°F	COMPOUND 20 W/O ANTIOZONANT R.T.	COMPOUND 20 W/O ANTIOZONANT 250°F	COMPOUND 4 (S.B.R. 1500) WITH ANTIOZONANT R.T.	COMPOUND 4 WITH ANTIOZONANT 250°F	COMPOUND 4 W/O ANTIOZONANT R.T.	COMPOUND 4 W/O ANTIOZONANT 250°F
1 THIXON (12809/CB3)	A	R @ 110	R @ 85	R @ 130	R @ 95	R @ 140	S.B @ 85	R @ 145	S.B @ 75
	B	R @ 120	R @ 50	R @ 140	R @ 95	R @ 140	S.B @ 70	R @ 145	S.B @ 55
	C	75R/25R.C @ 110 [4]	R @ 30	95R/5R.C @ 150	60R/40R.C @ 55	R @ 140	S.B @ 70	S.B @ 80	S.B @ 9[illegible]
2 CHEMLOK (205/232)	A	R @ 95	R @ 75	R @ 120	R @ 80	R @ 130	R @ 80	R @ 140	S.B @ 50
	B	R @ 105	R @ 85	R @ 120	R @ 85	R @ 130	S.B @ 75	R @ 150	S.B @ 70
	C	R @ 110	R @ 60	R @ 110	R @ 65	R @ 130	S.B @ 70	R @ 140	S.B @ 75
3 CHEMLOK (205/222)	A	95R/5R.C @ 95	90R.C/10R @ 40	R @ 110	S.B @ 115	R.C @ 40	R.C @ 20	R.C @ 40	S.B @ 60
	B	66R.C/33R @ 100	85R.C/15R @ 35	R @ 130	S.B @ 105	R.C @ 40	S.B @ 70	R.C @ 40	S.B @ 45
	C	50R/50R.C @ 75	60R.C/40R @ 50	R @ 115	R @ 80	R.C @ 65	S.B @ 80	60R.C/40R @ 90	S.B @ 55
4 CHEMLOK (205/220)	A	R @ 55	75R/25R.C @ 80	R @ 150	R @ 105	R.C @ 70	R @ 70	R.C @ 35	S.B @ 70
	B	R.C @ 50	95R/5R.C @ 100	R @ 130	S.B @ 105	R.C @ 40	R.C @ 10	60R.C/35CP/5R @ 70	S.B @ 45
	C	60R.C/40R @ 105	95R.C/5R @ 40	R @ 140	S.B @ 95	R.C @ 30	R.C @ 10	R.C @ 60	95R.C/5R @ 15

BONDING SYSTEMS	[3] ADHESIVE APPLICATION SCHEME	COMPOUND 23 (S.B.R. 1609/CIS4 POLYBUTADIENE) WITH ANTIOZONANT R.T.	COMPOUND 23 WITH ANTIOZONANT 250°F	COMPOUND 23 W/O ANTIOZONANT R.T.	COMPOUND 23 W/O ANTIOZONANT 250°F	COMPOUND 28 (HYTRANS) WITH ANTIOZONANT R.T.	COMPOUND 28 WITH ANTIOZONANT 250°F	COMPOUND 28 W/O ANTIOZONANT R.T.	COMPOUND 28 W/O ANTIOZONANT 250°F
1 THIXON (12809/CB3)	A	80R/20R.C @ 110	R @ 105	R @ 115	R @ 110	R @ 100	95R/5R.C @ 70	R @ 106	R @ 90
	B	80R.C/20R @ 95	80R/20R.C @ 85	95R/5R.C @ 125	95R/5R.C @ 95	80R/20R.C @ 15	R @ 25	R @ 120	R @ 85
	C	95R.C/5R @ 90	75R/25R.C @ 75	80R/20R.C @ 110	R @ 100	80P/20R.C @ 115	R @ 50	R @ 120	R @ 70
2 CHEMLOK (205/232)	A	R @ 90	R @ 70	R @ 105	R @ 75	R @ 110	R @ 70	R @ 130	R @ 70
	B	R @ 115	R @ 80	R @ 130	R @ 65	R @ 115	95R/5R.C @ 75	R @ 125	90R/10R.C @ 80
	C	R @ 125	R @ 70	R @ 130	R @ 75	R @ 110	R @ 75	R @ 125	R @ 75
3 CHEMLOK (205/222)	A	50R/50R.C @ 90	R @ 90	75R/25R.C @ 130	R @ 105	R.C @ 70	95R/5R.C @ 90	50R/50R.C @ 110	R @ 80
	B	R @ 120	R @ 90	R @ 120	R @ 100	95R.C/5R.F @ 70	95R/5R.C @ 90	R @ 120	R @ 90
	C	R @ 105	R @ 65	R @ 120	R @ 95	80R.C/20R @ 80	R @ 100	R @ 120	95R/5M @ 75
4 CHEMLOK (205/220)	A	75R.C/25R @ 85	R @ 75	R.C @ 75	90R.C/10R @ 60	95R.C/5R @ 85	50R/50R.C @ 55	R.C @ 60	R @ 95
	B	R @ 115	R @ 70	95R.C/5R @ 75	95R.C/5R @ 45	85R.C/15R @ 95	85R/15R.C @ 75	75R.C/25R @ 100	R @ 105
	C	75R/25R.C @ 105	R @ 90	90R/10R.C @ 110	R.C @ 40	95R.C/5R @ 75	75R/25R.C @ 65	70R/30R.C @ 110	R @ 90

[1] 90° PEEL STRENGTHS DETERMINED ON TEST SPECIMENS AFTER 10 MINUTE SOAK AT 250°F

[2] TYPE OF FAILURE

R - FAILURE IN THE RUBBER
RC - FAILURE AT THE RUBBER-COVER CEMENT INTERFACE
CP - FAILURE AT THE COVER CEMENT INTERFACE
M - FAILURE AT THE METAL-PRIMER INTERFACE
SB - STOCK BREAK

[3] ADHESIVE APPLICATION SCHEME

A - PRIMER + 1 COAT COVER CEMENT
B - PRIMER + 2 COATS COVER CEMENT
C - PRIMER + 3 COATS COVER CEMENT

[4] COMPOSITE FAILURE

INDICATES 75 PERCENT R FAILURE AND 25 PERCENT R.C FAILURE @ 110 LBS/IN

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6. Rock Island Arsenal R&E Div. Technical Report 66-2517, "Development and Service Testing of Rubber Track Pads," August 1966.

7. U. S. Army Weapons Command Science and Technology Laboratory Report RE TR 70-121, "Development of Rubber Pads for Tracked Vehicles," February 1970.

APPENDIX

ELASTOMER DESCRIPTION

Trade Name	Description	Company
Genthane S	Millable Polyester Urethane	General Tire & Rubber Co.
Genthane SR	Millable Polyester Urethane	General Tire & Rubber Co.
Vibrathane 5004	Millable Polyester Urethane	Uniroyal, Inc.
Diene	Cis-trans Polybutadiene	Firestone Tire & Rubber Co.
Stereon 720	Stereospecific SBR (10% styrene)	Firestone Tire & Rubber Co.
Stereon 750	Stereospecific SBR (18% styrene) (37.5 parts oil extended)	Firestone Tire & Rubber Co.
High Mooney EPDM	Royalene F65-3-9H	Uniroyal, Inc.
Chlorobutyl HT-1066	Chlorinated Butyl	Enjay Chemical Co.
SBR 4678	Oil-Black Masterbatched SBR (40 parts black - 5 parts oil)	Ameripol, Inc.
CB 221 Polybutadiene	Cis-Polybutadiene	Ameripol, Inc.
Philprene 1609	Oil-Black Masterbatched SBR (40 parts black - 5 parts oil)	Phillips Petroleum Co.
Cis-4-1350 Polybutadiene	Oil-Black Masterbatched Polybutadiene (80 parts black - 35 parts oil)	Phillips Petroleum Co.
EP syn EPDM	Fast Curing EPDM	Copolymer Rubber & Chemical Corp.
ECD 729	Experimental EPDM	E. I. duPont de Nemours & Co.
Nordel 1320	Ethylene Propylene Terpolymer	E. I. duPont de Nemours & Co.
Neoprene GNA	Polychloroprene	E. I. duPont de Nemours & Co.
HYTRANS 1227-158-2	85/15 Butadiene/Styrene Copolymer (37.5 parts oil extended)	U. S. Industrial Chemicals Co.
HYTRANS 1227-158-4	90/10 Butadiene/Isoprene Copolymer (37.5 parts oil extended)	U. S. Industrial Chemicals Co.
HYTRANS 1227-158-6	85/15 Butadiene/Styrene Copolymer	U. S. Industrial Chemicals Co.
HYTRANS 1227-158-7	90/10 Butadiene/Isoprene Copolymer	U. S. Industrial Chemicals Co.
HYTRANS 1227-176-1	85/15 Butadiene/Styrene Copolymer (37.5 parts oil extended)	U. S. Industrial Chemicals Co.
HYTRANS 1227-176-2	90/10 Butadiene/Isoprene Copolymer (37.5 parts oil extended)	U. S. Industrial Chemicals Co.
Chemlok 205	Rubber-to-metal bonding agent	Hughson Chemical Co.
Chemlok 220	Rubber-to-metal bonding agent	Hughson Chemical Co.
Chemlok 222	Rubber-to-metal bonding agent	Hughson Chemical Co.
Chemlok 232	Rubber-to-metal bonding agent	Hughson Chemical Co.
THIXON D-12809	Rubber-to-metal bonding agent	Dayton Chemical Products Div. Whittaker Corp.
THIXON CB-3	Rubber-to-metal bonding agent	Dayton Chemical Products Div. Whittaker Corp.